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Procedures and Equipment for FUMIGATING EUROPEAN PINE SHOOT MOTH ON ORNAMENTAL PINES

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W. H. Klein
R. M. Thompson

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FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE · FOREST SERVICE

SUMMARY

This is the second in a series of three reports on experimental fumigation for complete kill of the European pine shoot moth on pines in residential areas and nurseries. It describes the procedures and equipment that were developed and used for the actual fumigation tests described in the other two reports. Tests were made concerning the physical control of gas concentration in the three types and various sizes of portable chambers that were fabricated. Recommendations for the proper use and care of fumigation equipment are made for the use of operators concerned with fumigating infested trees in residential areas and nurseries.

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FOREST AND RANGE EXPERIMENT STATION
R. W. Cowlin, Director Portland, Oregon

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

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INTRODUCTION

Discovery of the European pine shoot moth in 1959 on ornamental pines in Seattle, Wash., exposed a serious threat to the native pine forests of the western States. The problems created by this threat were studied by representatives of private, State, and Federal organizations, and needed actions were recommended through the Northwest Forest Pest Action Council. One of these actions was experimental fumigation of infested pines with methyl bromide to determine whether this method could be used to eradicate the shoot moth. During the period December 1960 to November 1961, four series of tests were conducted to determine the effectiveness of fumigation at various times of year. A fifth test was made in November 1961 to determine the feasibility of treating all the pine stock in a typical commercial nursery growing numerous kinds of ornamental trees and shrubs.

This is the second in a series of reports on the experimental fumigation with methyl bromide. It consists of two parts. One describes the procedures developed and equipment used during the period of experimentation; it is to provide guidance for those immediately concerned with use of the fumigation technique. The second part describes tests of mechanical factors pertinent to devising the fumigation technique previously reported,[1] hence is primarily for the information of other researchers.

The equipment and apparatus described were largely devised or adapted from that used by Agricultural Research Service in large-scale fumigation of Hall scale and Khapra beetle in California. The primary objective was to develop a reliable means for obtaining precisely controlled conditions for fumigation tests on single pines in residential areas. Modifications were made for the test on pines growing singly and in rows in a nursery. The equipment and procedures developed to date are considered operational for practical use.

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[1] Carolin, V. M., Klein, W. H., and Thompson, R. M. Eradicating European pine shoot moth on ornamental pines with methyl bromide. Pac. NW. Forest and Range Expt. Sta. Res. Paper 47, 16 pp., illus. 1962.

PART I

In this part of the report, fumigation procedures and equipment are described and discussed. Operational procedures, based on experience in experimental tests, are recommended.

PROCEDURES IN FUMIGATION

The actual fumigation work was performed by a team consisting of eight men: a crew foreman who supervised and coordinated the crew's activities and obtained gas analyses; an assistant whose primary duty was introducing the fumigant; and two 3-man crews who assembled, guarded, and disassembled the fumigation chambers. The crew foreman was responsible for keeping records on gas analyses, and each guard recorded temperatures inside and outside designated chambers.

Preparation of trees for fumigation involved two steps: (1) removing moisture and debris from the tree crown and (2) enclosing the tree with a gas-tight chamber. The first step was accomplished with a 6-inch squirrel-cage fan type of blower, operated by a portable gasoline engine. The second step was achieved with a wooden frame fitted with a plasticized nylon jacket. The jacket overlapped and was fastened to a ground cloth of the same material which fitted snugly around the base of the tree. The seal around the tree base was obtained by packing with wet sand. Lengths of flexible plastic tubing for applying and sampling the gas were run into each chamber and suspended at predetermined heights. When the temperature in a chamber had to be raised, 115-volt strip heaters, operated on house current were positioned on bricks at the bottom of the chamber.

The gas was measured, released into an application line, and heated as it followed the application line into the fumigation chamber.

During fumigation, checks and measurements were made as follows:

1. Actual gas concentrations were measured with a thermal conductivity gas analyzer. The gas analyzer was powered either by 115-volt house current or a 12-volt car battery with an AC-DC inverter (fig. 1).

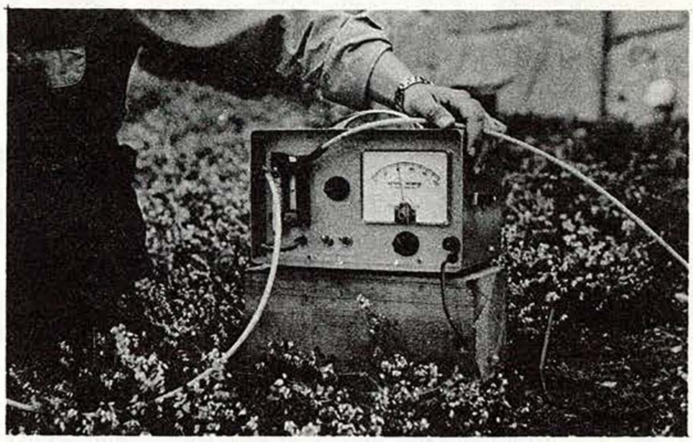


Figure 1. – Fumiscope used to measure concentrations of methyl bromide.

2. Temperatures in the chamber were measured by means of an 8-inch photographic-solution thermometer inserted through the nylon jacket at midchamber height (fig. 2).

3. Gas leaks were detected with a halide gas detector (fig. 3). When methyl bromide in the air reaches a concentration of 25 parts per million, the flame in the detector becomes greenish, indicating potential danger. At higher concentrations, the flame becomes blue.

Evacuation of gas from chambers at the end of fumigation was accomplished either with a heavy-duty vacuum cleaner motor with a length of rigid metal tubing attached, or with a squirrel-cage blower with flexible tubing attached. As a safety measure crew members, opening the seal between the nylon jacket and the ground tarp to insert an evacuating device, were equipped with gas masks.

Figure 2. – Recording chamber temperature from 8-inch photographic-solution thermometer.

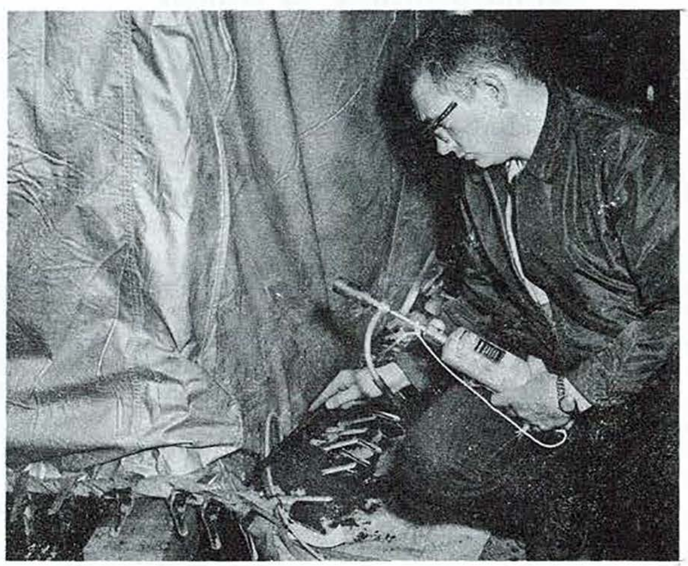


Figure 3. – Searching for gas leaks with halide detector.

EQUIPMENT AND APPARATUS

Fumigation Chambers

Requirements for the chambers were that they should be portable, prefabricated for ease in assembly and disassembly, and strongly constructed but with weight held to a minimum. The tarpaulin material used for the jacket and ground cloth had to be resistant to abrasion, supple enough to be folded, and light enough to be stitched on a commercial sewing machine. The coating placed on the tarpaulin material needed to be resistant to weather, somewhat elastic, and above all gasproof.

Several types and sizes of chambers were built for use in different tests. Construction details were improved as tests were carried on, without altering the capacity or sorptive characteristics of the chambers.

Initially, four sizes of cubical chambers were tested: (1) 3' x 3' x 3' (27 cubic feet), (2) 5' x 5' x 5' (125 cubic feet), (3) 10' x 10' x 10' (1,000 cubic feet), and (4) 12' x 12' x 14' (2,016 cubic feet). Several chambers of each type were built, using the same basic design. Chamber frames consisted of 1" x 4" and 2" x 2" common lumber, fastened at the corners with 3-inch carriage bolts. On the 1,000- and 2,016-cubic-foot chambers, the frames were diagonally braced with light cable wire which was tightened with turnbuckles. Figure 4 illustrates the basic construction details.

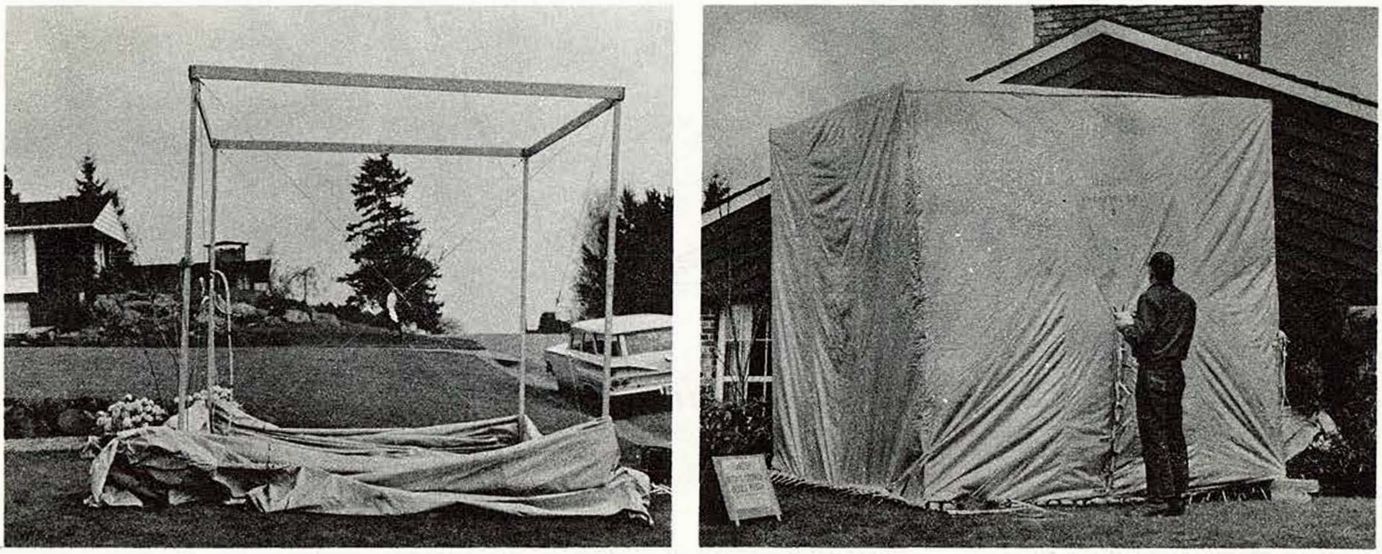


Figure 4. – The 10' x 10' x 10' cubical fumigation chamber; A, the uncovered frame; B, completed chamber.

Experience with these prototype chambers during initial tests revealed shortcomings. The 3' x 3' x 3' chambers yielded significantly lower gas readings than other chamber sizes and the 12' x 12' x 14' chamber proved too cumbersome, hence these two sizes were not used for the yearlong tests. The 5' x 5' x 5' chamber was satisfactory as originally developed. The 10' x 10' x 10' chamber was modified to facilitate its use. The basic components of the modified 10-foot chamber were two 6-foot-high prefabricated sides that could be extended up to 10 feet in height (fig. 5). Assembly consisted of connecting the prefabricated sides at each corner with 1" x 4" crosspieces by metal pins dropped through strap hinges. Additional diagonal bracing was provided by a series of lightweight metal chains tightened by turnbuckles. After the covering was in place, the entire frame was extended to its full height. This operation can be accomplished by two men, more efficiently by three men.

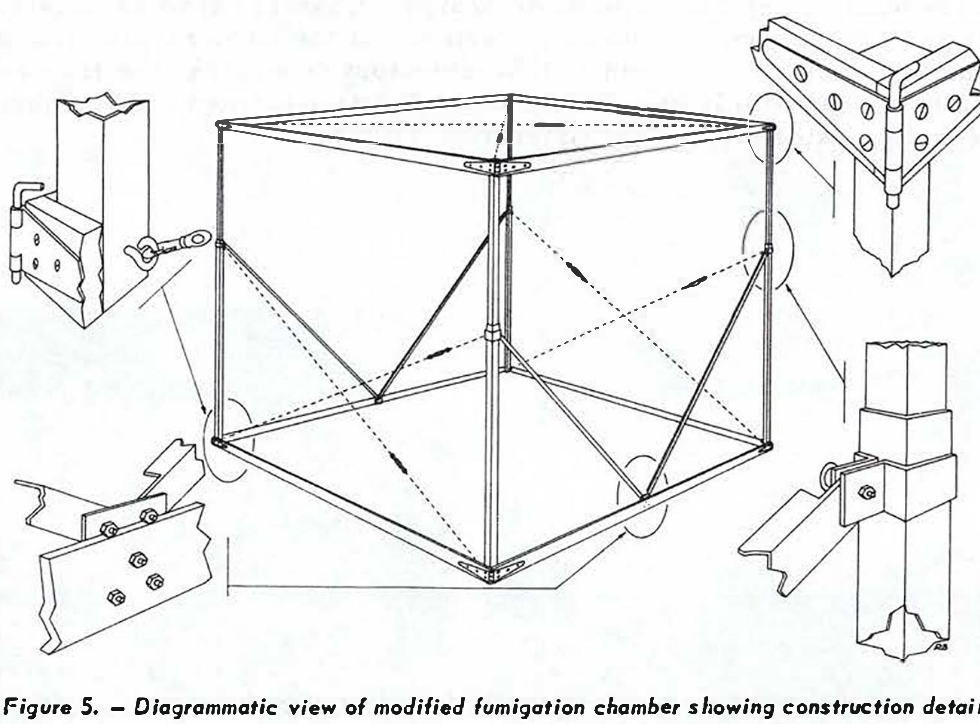


Figure 5. — Diagrammatic view of modified fumigation chamber showing construction details.

A cylindrical chamber was developed as a possible substitute for the 3- and 5-foot cubical units. The frames consisted of 12-gage welded wire mesh 3 feet and 5 feet high, respectively. The mesh was cut at predetermined lengths, corresponding to circumferences which produced volumes of 25 and 100 cubic feet, respectively. Eight inches were added to each circumference for overlap and joining. The top and bottom strands were taped or covered with plastic tubing to prevent the sharp ends from piercing the nylon jacket (fig. 6).

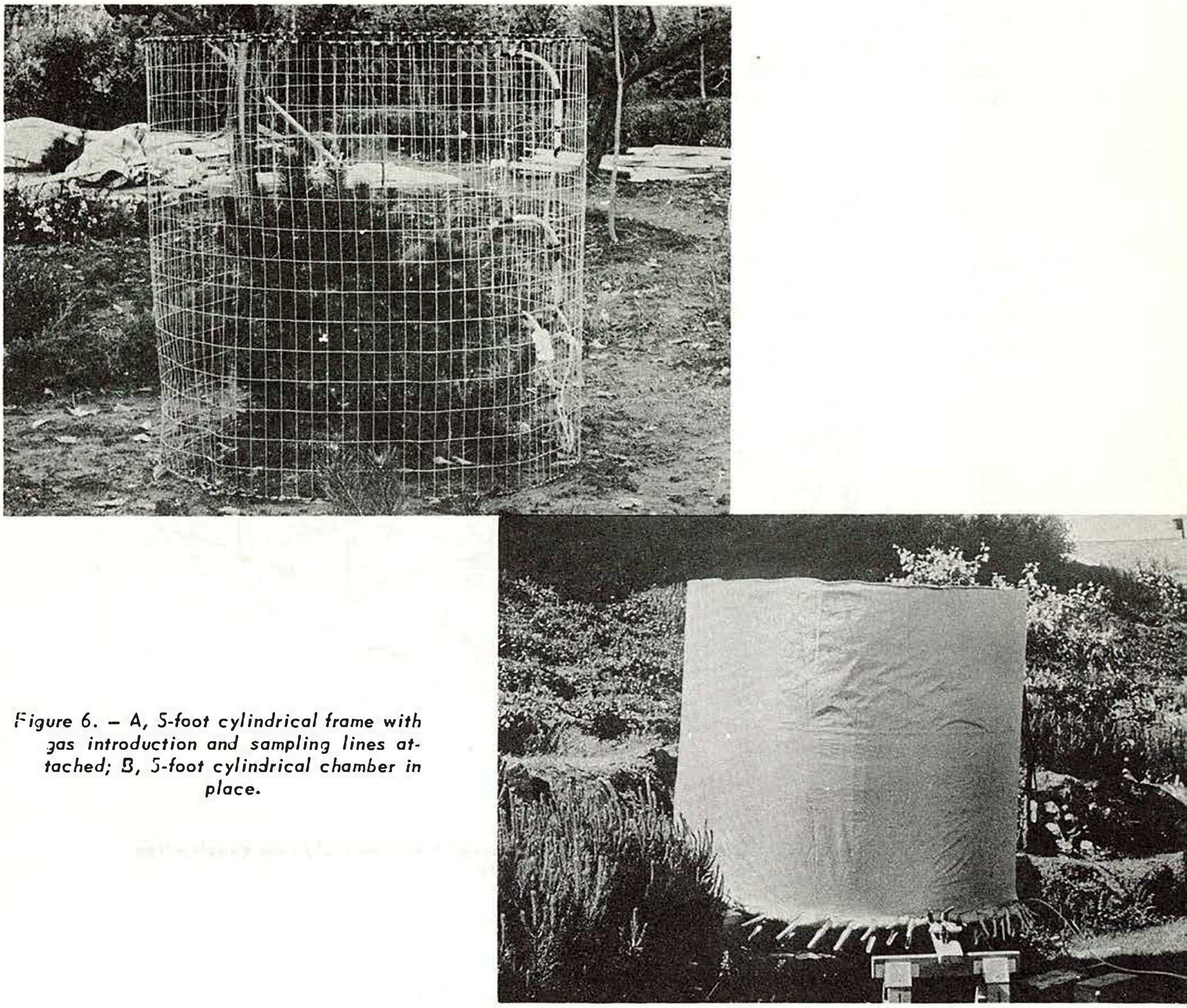


Figure 6. — A, 5-foot cylindrical frame with gas introduction and sampling lines attached; B, 5-foot cylindrical chamber in place.

An elongated version of the 5-foot cubical chamber was developed for treating rows of trees in a nursery. The chamber was adjustable so that it could be adapted to various tree heights, row widths, and row lengths. It consisted of a plasticized wood frame that could be adjusted in both height and width from 4 to 7 feet and to any length in multiples of 5 feet (fig. 7). Vertical and horizontal bracing were interchangeable, and each section was slotted for adjustment. Longitudinal members were 5-foot 2 by 2's so constructed that they could be fitted into the corners of the vertical and horizontal braces and progressively added to permit lengthening of the entire frame. Additional cross bracing was provided by wire or plastic rope.

Plasticizing involved treatment with a nonsorptive plastic paint, using a spray gun. For convenience one brand of paint--Pee Gee Devran Chemkoatt 600--was used both for these wood frames and the nylon tarpaulins. For treatment of wood members, Senox 63, Sherwin-Williams' phenolic lines varnish No. V76-V-C7, and equivalent formulations are also satisfactory.

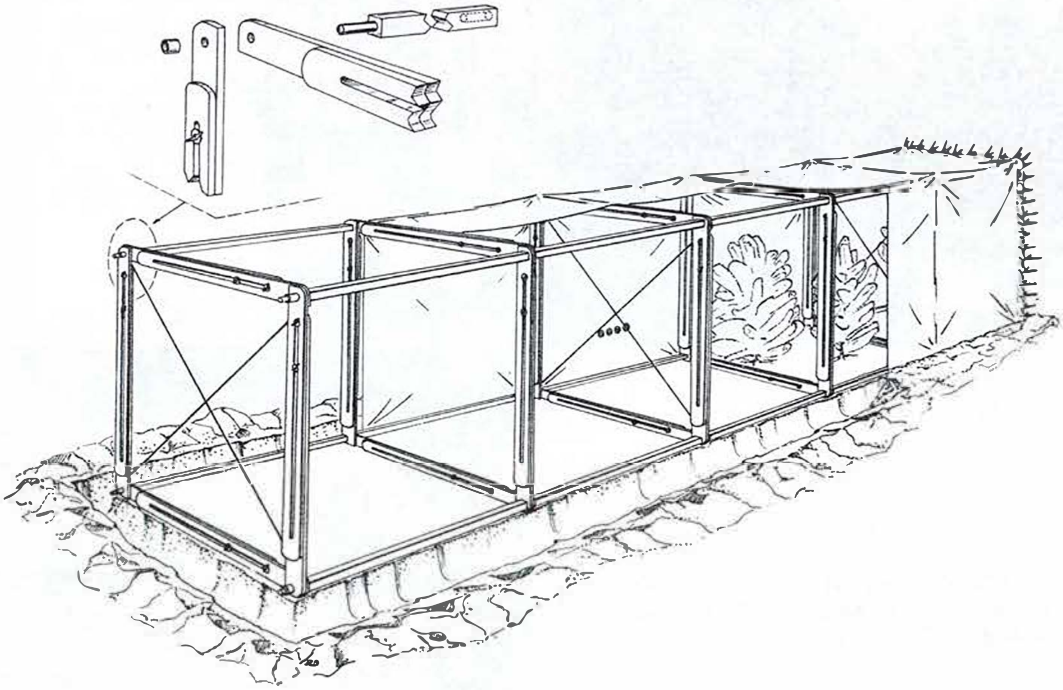


Figure 7. – Example of 25-foot-long portable chamber showing construction details.

Chamber Covers

The two most important factors to consider in selecting a cover for a field fumigation chamber are its gas-retention qualities and its durability. Polyethylene sheeting, commonly used on fumigation operations, retains gas very well but does not hold up under repeated use. The material adopted for the shoot moth eradication tests was 7-gage plasticized nylon of the type used by Agricultural Research Service for the Hall scale and Khapra beetle eradication programs. This material was used exclusively for both the chamber jackets and the ground cloths.

Prior to construction of the jackets, the plasticized nylon material was treated with a coat of silver vinyl plastic, Code 0249A, Flexfirm Products, El Monte, Calif., to decrease permeability and reduce solar radiation. The material was then cut to conform to the size and shape of the chamber frame, allowing a few inches for overlap and double seam construction. Material was cut into as few pieces as possible to reduce the number of weakening seams and the probability of leakage. Heavy-gage nylon thread was used throughout. All material was sewed on a commercial sewing machine. Aprons, 1 foot wide, were sewed to the bottom of the jackets to allow for a rolled overlap with the ground tarp. On the jacket for the 10-foot chamber, a 5-foot gusseted slot was placed in the middle of one side to permit access to the inside after the jacket was in place.

Ground tarps were cut 1 foot wider than the frames to match the jacket overlap so that both could be rolled and clamped together for a tight seal. Slits were cut half way through the tarps so that they could be positioned around the base of the tree. Gussets were sewed to both edges so that the opening could be sealed by rolling them together and securing with spring clamps (fig. 8). Better positioning of the square tarp was obtained by placing the slit diagonally, that is, from a corner to the center. Circular tarps for the cylindrical chambers were also provided with a slit. All edges of the ground tarps were double seamed to prevent fraying.

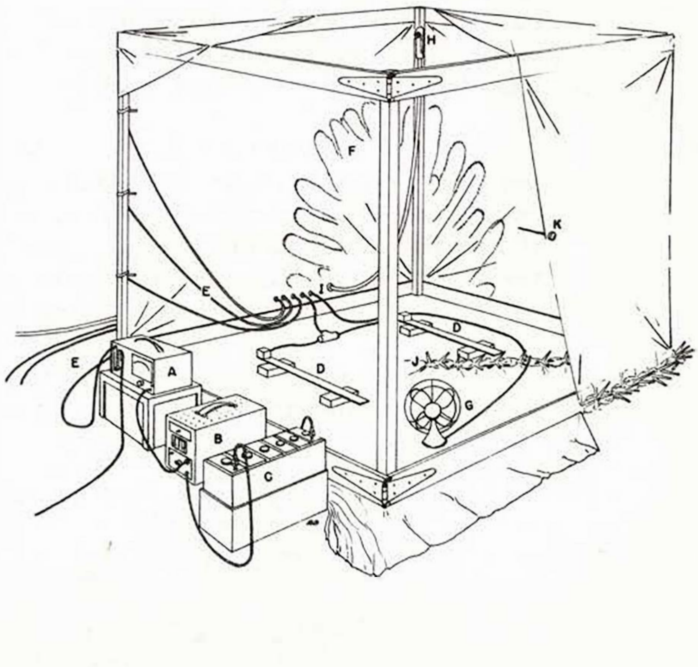


Figure 8. – Diagram of a complete fumigation assembly, showing type and position of equipment. A, fumiscope; B, inverter; C, 12-volt battery; D, strip heaters; E, sampling lines; F, tree; G, fan; H, gas introduction line; I, grommets to admit sampling and introduction lines; J, sand and ground tarp roll at base of tree; and K, thermometer.

Jackets and ground tarps were numbered and a record kept of their use. Those showing evidence of wear were replasticized. Most frequently, the weak point and source of gas leakage was the seams; these contained numerous minute holes along the stitches made by the sewing machine needle.

Jackets for the elongate chambers were not "custom tailored" as were those for the cubical chambers. A single tarp was used for the top and sides corresponding to the frame dimensions and allowing for a minimum of 1-foot overlap at the bottom and ends. The ends and bottom were joined by rolling and clamping the main tarp with separate end and bottom tarps to make a complete seal.

Brass grommets were placed in the lower section of each jacket to allow for the entrance of application and sampling lines. A tight seal was obtained by wrapping the tubing with plastic tape and forcing it through the grommets. At the start of the tests, these lines entered the chamber between the jacket and ground tarp and were rolled into the overlap. This procedure was soon abandoned because it created a potential source of leakage and sometimes pinched the tubing, thus cutting off or restricting gas flow.

Devices for Gas Manipulation

Throughout the tests efforts were made to develop increasingly efficient and safe equipment.

Applicators

One type of applicator is shown in figure 9. This type is used for applying methyl bromide in whole-can amounts (half pound and 1 pound). The operation begins by closing the two cam valves, inserting the methyl bromide cans into the holders, and puncturing the cans by turning them clockwise against a cutter. One valve is then opened, allowing the gas from one can to escape through the heating coils into the chamber. When this can is empty, the valve is closed and the second valve opened to empty the other can. Before the second can is empty, a third can is attached to the spot left vacant by the first can. The process is continued until the required dosage is obtained. Glass sight lines are inserted below each valve to permit viewing the discharging liquid so that the cans will not be removed until empty.

The second type of applicator is similar but contains a graduated plastic bottle inserted between the discharge valve and heating coils to permit measurements of small quantities of methyl bromide (fig. 10). The gas is released by filling the bottle to the correct level, closing the discharge valve, and opening the small valve between the plastic bottle and heating coils. High-pressure cam valves of the type used on the first applicator are also used on this model.

Both applicators use 1/4-inch fittings and valves. Adaptation to the 3/8-inch copper tubing is made by use of reducers. All fittings and valves are

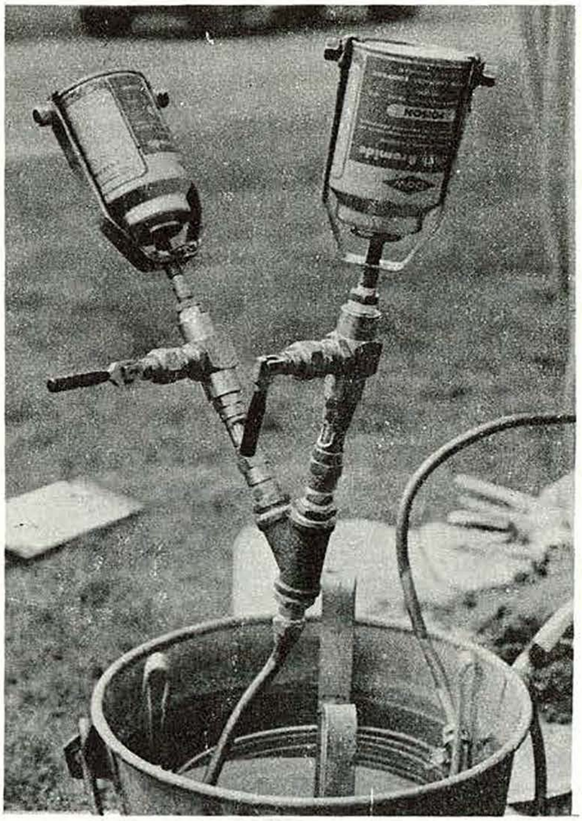


Figure 9. – Gas applicator and volatilizer used for dispensing ½-pound and 1-pound amounts of methyl bromide.

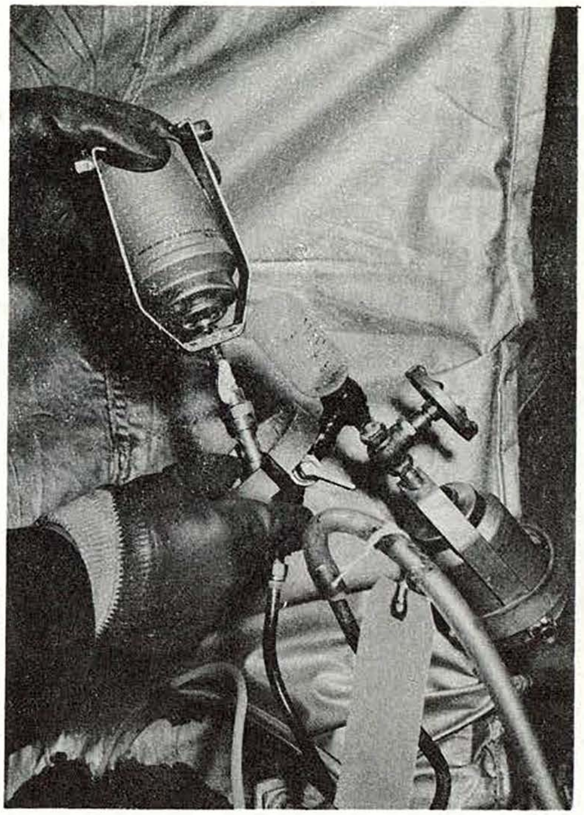


Figure 10. – Gas applicator used for dispensing small amounts of methyl bromide, measured in cubic centimeters.

brass except the cam valves which are stainless steel. Pipe joint compound is used to seal all connections.

Volatilizer

Complete vaporization of the liquid is accomplished by piping the liquid-vapor through 25 feet of coiled 3/8-inch copper tubing (fig. 9). The coils are placed in a pail filled with water heated to 180° F. The end of the heating coil is connected to 3/8-inch plastic tubing which is inserted into the chamber. Water is heated by a portable propane burner, and a standard thermometer is used to check water temperatures.

Heating Devices

Solar radiation raises temperatures inside the chambers. Full sunlight creates a differential of 20° to 25° F. between internal and external temperatures. When ambient temperatures are low, solar radiation aids in shortening the time of treatment. When ambient temperatures are high, solar radiation raises the chamber temperatures still higher, necessitating a shortening of the period of treatment.

Use of strip heaters is often desirable when fumigation is carried on during overcast winter days. Commercial 500-watt low-density heaters are used and connected in parallel to obtain maximum wattage (fig. 8). With air temperatures of 40° to 50° and heavy overcast, two heaters are required to heat the 5-foot chambers to temperatures of 70° to 75°. Under the same conditions, six heaters in the 10-foot chambers raised chamber temperatures only about 10°. Temperatures are controlled manually by disconnecting the power source when the desired temperature is almost reached and reconnecting after the temperature has dropped 2° to 3°. Temperatures are maintained within a 5° range of oscillation. House current powers the heaters; no more than two heaters are put on a single circuit to avoid overloading the line. Heaters are supported on bricks placed on the floor of the chamber. No insulation between the bricks and ground cloth is necessary.

Cooling Devices

Occasionally it is necessary to lower the chamber temperatures. One method was to sprinkle chambers with water; another was by shading with a large tarp suspended by poles. Sprinkling required a nearby water outlet and constant attention. Of the two methods tried, shading was far more convenient and effective.

Fans

Various kinds of electric fans can be used to insure gas circulation and an even distribution of heated air when strip heaters are used or solar radiation is high. Vacuum cleaner blower and standard 8-inch table fans are equally useful (fig. 8).

Evacuation Equipment

Two types of blowers were used, depending on chamber size. Large chambers were evacuated with a squirrel-cage blower powered by a gasoline engine. A 6-inch flex hose was attached to the intake side of the blower and inserted into an opening at the bottom of the fumigation chamber. The gas was disseminated into the atmosphere through a 10-foot nylon sleeve suspended vertically on a pole (fig. 11A).

The smaller chambers were evacuated by a vacuum cleaner blower connected to a 2-inch pipe placed into an opening in the chamber. The gas was drawn through a 12-foot pipe supported by a tripod before being dispersed into the air (fig. 11B).

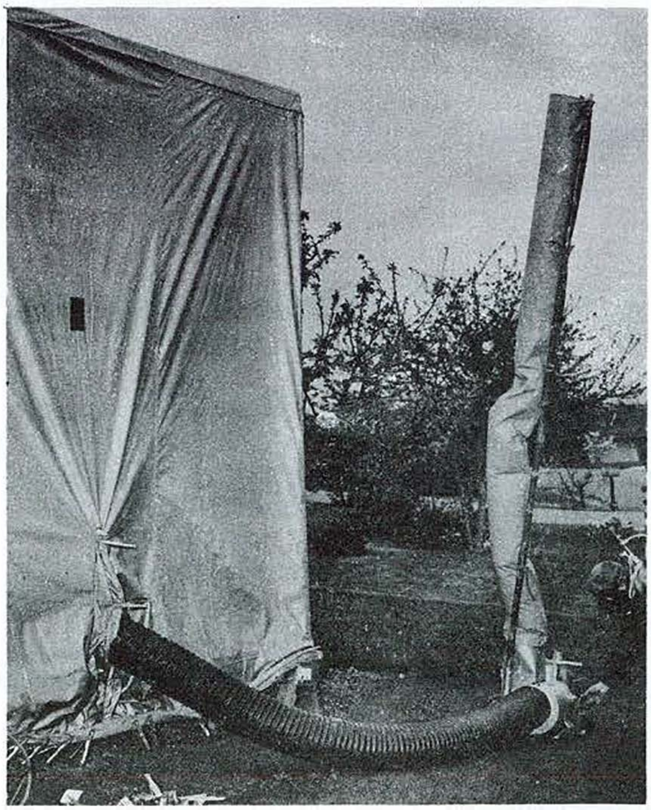
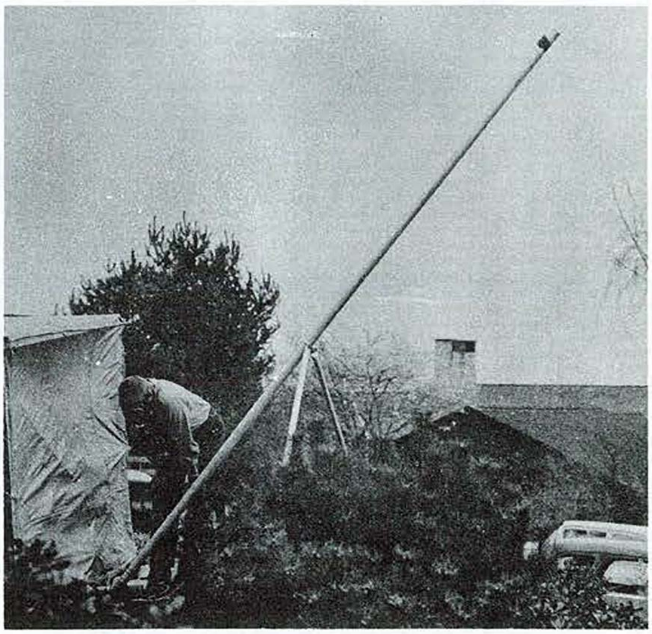


Figure 11. – Evacuation assembly; A, for 10-foot chamber and B, for 5-foot chamber.



Both types of blowers created a vacuum that was released by making a small opening in the side of the chamber opposite the point of evacuation.

During introduction of the gas, the man operating the applicator wore goggles and plastic gloves and took special precautions to insure that all fittings were tight.

A gas mask, equipped with a cannister for organic vapors, was worn by the crew member evacuating the gas. When records showed 60 minutes of use of the cannister, it was replaced.

A halide gas detector was used to detect leaks during fumigation and to check the general area around the chambers following gas evacuation (fig. 3). Leaks that developed around the rolled edges were stopped with wet sand (fig. 12). Disassembly of chambers was postponed until the chamber was shown to be free of gas.

Guards were stationed with each chamber or series of chambers. Warning signs were strategically placed to discourage onlookers. Used methyl bromide cans were carefully checked and safely discarded at the end of each day.

Figure 12. – Sealing a potential leak source with sand and water.

DISCUSSION

Chamber performance throughout the entire series of tests was good; physical characteristics were conducive to sustained use and resulted in satisfactory gas retention and distribution. Use of these chambers can be expected to have wide application in the field of fumigation.

Of the different types of chambers used in the series of tests, the cylindrical chambers proved to be the most efficient for trees 5 feet or less in height. Compared with the cubical chambers, the cylindrical chambers were lighter, cheaper, and easier to construct, easier to assemble and disassemble, and more compact. Because of their metal frames, the possibility of sorption by the frame was eliminated entirely. The circular cross section eliminated compounded corner folds of the chamber jacket with the ground tarps, which with the square frames was the most common source of detectable leakage. An important limitation of the cylindrical chambers is that rigidity decreases as the size of the chamber increases; i.e., the 3-foot frames are more rigid than the 5-foot frames. Construction of larger frames was not attempted because they would require additional bracing which would make them less portable and would increase assembly and disassembly time. Another disadvantage is that the wire frames will not withstand repeated kinking and bending. However, if this is avoided, they should last indefinitely.

The modified 10' x 10' x 10' cubical chamber performed well under all circumstances. Ease of assembly and disassembly was this unit's strong point. The fact that it can be adapted to heights ranging from 6 to 10 feet makes it versatile. The frame is exceptionally strong and should stand up well under repeated use; it is heavier than the prototype chamber but not heavy or cumbersome enough to restrict its portability. Cost of materials is approximately $40 for the modified chamber, as compared with $5 to $10 for the prototype chamber.

The elongate chamber developed for fumigating rows of trees in commercial nurseries was basically satisfactory. The chief difficulty encountered was in the use of a ground tarp. It is not possible to wrap the tarp tightly around the base of every tree in a row. An alternate method is to bring the edges of two tarp sections up to the trunks of the trees and pack the space with wet sand, overlapping the sand onto the tarps. It is not yet definitely established whether soaking the ground alone is a satisfactory substitute for a ground tarp. Trenching the ends of the nylon jacket without using a ground tarp saves considerable time in setting up these chambers.

Most of the trees encountered in residential districts and in commercial nurseries can be successfully and conveniently treated with methyl bromide using the 3- and 5-foot cylindrical chambers, the modified 10' x 10' x 10' cubical chamber, and the elongate chamber. However, no convenient method exists for treating trees over 10 feet in height. The time required and the difficulties encountered in setting up a 12' x 12' x 14' chamber make the use of

such large cages of marginal practicability. The problems in enclosing larger trees with a tarp supported by poles are even greater and include the critical one of determining the enclosed volume within the required limits of accuracy. This leaves unresolved how to eradicate the shoot moth from the relatively few large trees in a community, short of destroying them.

Constant maintenance of equipment and apparatus is vital to a successful fumigation program. Chamber covers and ground tarps must be examined at regular intervals; those showing minor wear should be replasticized; those with loose stitching should be discarded. The portion of the application line fastened to the volatilizer should be inspected frequently; before the tubing becomes rotted from the effects of hot water vapor, it should be cut back beyond the point of discoloration. The applicator should be watched carefully for signs of gas leakage. Maintenance of equipment provides insurance that fumigation will be safe as well as successful.

RECOMMENDATIONS

Types of portable chambers developed in this study and recommended for use in fumigating trees with European pine shoot moth are: 5' x 5' x 5' and 10' x 10' x 10' cubical chambers, an elongate cubical chamber adjustable to 25 feet in length, and 3- and 5-foot-high cylindrical chambers. Chamber size and type should be selected according to size and shape of tree to be fumigated. Some space must be left between the sides of the chamber and tree periphery for gas and air circulation.

Effective use of these chambers for complete kill of the shoot moth with minimum damage to the treated pines requires accurate records on fumigation in terms of gas concentration, time, and temperature. All crew members must be conscious of the importance of periodic measurements of these factors.

Before chambers are used for methyl bromide fumigation, they should be carefully checked for adequate gas retention by the thermal conductivity method. A fumiscope, Gow Mac, or similar measuring device is acceptable. Periodic checks are necessary to insure that chambers remain in good operating condition.

Leakage and sorption of gas should be minimized by painting chamber frames, floor racks, pallets, and other wood materials used in chamber construction with a special nonsorptive paint such as Pee Gee Devran Chemkoatt 600, Senox 63, Sherwin-Williams' phenolic lines varnish No. V76-V-C7, or equivalent.

Gas must be applied in precisely measured amounts by means of safe, accurately calibrated applicators, such as described in this report. Gas should always be volatilized by using a water bath at approximately 180° F.

Fans were found unnecessary for satisfactory distribution of gas in most experimental treatments. However, it is necessary to be alert for special situations where circulation of gas or heat is desirable. When temperatures are high, or when the weather is cold and windy, forced circulation of the gas-air mixture inside the chamber is desirable to obtain uniform distribution of heat and realistic temperature readings. Such circulation is especially needed when the elongate type of cage is being used.

Safety measures should be constantly observed, particularly during gas introduction and chamber evacuation. Protective equipment should be worn by the man operating the gas applicator and those working around the chamber during evacuation. Other members of the crew and bystanders should keep their distance from the chambers until these operations are completed. It is particularly important that an accurate record of use of gas masks be marked on the gas cannisters, so that the cannisters may be replaced prior to exhaustion.

PART II

This part of the report is concerned with the basic tests that were made to develop standardized methods for the experimental fumigation, the results of which have previously been reported.[2] Primarily, the developmental tests concerned factors affecting mechanical control of gas concentration within the fumigation chambers. The results of these basic tests are reported to document the recommended fumigation techniques.

EFFECTS OF TREE CROWN DENSITY, CHAMBER SIZE, AND FORCED CIRCULATION

The variable measured was gas concentration, expressed in ounces per 1,000 cubic feet, at different chamber heights and at regular intervals of time. A total of 12 pines was used.

Crown density was of two types: (1) open and thin, represented by Scotch pine, and (2) closed and dense, represented by mugho pine for the smaller trees and Japanese black and red pines for the larger trees. Three chamber sizes were used: 3' x 3' x 3', 5' x 5' x 5', and 10' x 10' x 10'. Two types of circulation were provided: (1) forced circulation for 25 minutes immediately after gas introduction, using a vacuum cleaner motor, and (2) no circulation except that induced by heating the gas during introduction. A gas concentration of 5 pounds per 1,000 cubic feet was used, and duration of test was 3 hours.

Methods

Two trees of each crown-density class were treated in each size of chamber. Gas concentration was measured at half-hour intervals at three crown heights within each chamber. Each chamber was divided into thirds and tubing for gas samples run to the middle of each third. The tubing was color-coded to avoid confusion when taking gas measurements. This was a split-plot experiment in which the individual chambers constituted the main plot, and chamber position and time interval were subplots. Analysis was made to determine which of the following factors or combination of factors were related to significant differences in gas concentration: (1) crown density, (2) circulation, (3) chamber size, (4) position in chamber, and (5) time after gas introduction.

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[2] Carolin, V. M., Klein, W. H., and Thompson, R. M. Eradicating European pine shoot moth on ornamental pines with methyl bromide. Pac. NW. Forest and Range Expt. Sta. Res. Paper 47, 16 pp., illus. 1962.

Results

Data obtained during these tests are shown in table 1. A significantly lower gas concentration was found in the 3' x 3' x 3' chambers, as compared with the 5' x 5' x 5' and 10' x 10' x 10' chambers. No significant difference was found between crown density, circulation, chamber position, or duration of time in a period of 3 hours. It may be concluded that crown density does not interfere with gas circulation, that stratification of the gas does not occur if the gas is introduced hot, and that gas loss over a period of 3 hours is not appreciable. Use of the 3' x 3' x 3' chamber is not recommended until the lower gas concentrations can be explained and the condition corrected.

EFFECTS OF TIME AND CHAMBER SIZE OVER A 5-HOUR PERIOD

Gas concentration was again the variable measured, this time with four different chamber sizes and at three different chamber heights. The chamber size added was 12' x 12' x 14'. Only one tree species, lodgepole pine, was used, and crown density was not a factor in analysis. A gas concentration of 5 pounds was used, and the fumigation period was 5 hours.

Methods

Two trees were treated in each chamber size. Gas concentration was measured every hour at three different crown positions. Chamber temperature and outside air temperature were recorded every hour to provide general control. This was a split-plot experiment, and analysis was to determine whether significant changes in gas concentration occurred over a 5-hour period with the four chamber sizes.

Results

Gas concentrations in the 3' x 3' x 3' chambers were significantly lower than those in the other three chamber sizes, as before. Rate of gas loss was found to be linear, indicating that gas stabilization did not actually occur in a 5-hour period. Differences between initial and final gas readings differed as much as three-quarters of a pound per 1,000 cubic feet. On two trees, a sudden drop in temperature to below 40° F. was associated with an increase in gas concentration. This is unexplained, except that sorption by the wood frames may change with temperature.

Table 1.--Effects of tree crown density, chamber size, and forced circulation on methyl bromide gas concentrations (at rate of 5 pounds (80 ounces) per 1,000 cu. ft.) over a 3-hour period; Seattle, Wash., December 1960

Chamber size and type of circulation[1]	Average chamber temperature[2]		Elapsed time after gas introduction	Gas concentration in chamber (per 1,000 cu. ft.)[3]									
				With dense-crown trees					With open-crown trees				
	With dense-crown trees	With open-crown trees		Lower third	Mid-point	Upper third	Average	Total gas loss	Lower third	Mid-point	Upper third	Average	Total gas loss
	---Degrees F.---		Hours	---------- Ounces ---------				Percent	--------- Ounces ----------				Percent
3' x 3' x 3' (27 cu. ft.):													
Fan	46	44	1/2	44	42	42	--	--	55	53	52	--	--
			2-1/2	30	26	27	28	65	29	28	27	28	65
No fan	44	50	1/2	52	47	49	--	--	50	49	49	--	--
			2-1/2	38	36	36	37	54	21	22	21	21	74
5' x 5' x 5' (125 cu. ft.):													
Fan	49	39	1/2	64	64	65	--	--	60	60	61	--	--
			2-1/2	74	70	64	69	14	58	58	58	58	28
No fan	51	44	1/2	74	71	70	--	--	73	75	71	--	--
			2-1/2	70	67	73	70	12	64	64	64	64	20
10' x 10' x 10' (1,000 cu. ft.):													
Fan	55	41	1/2	68	68	68	--	--	74	72	72	--	--
			2-1/2	59	61	60	60	25	80	82	74	79	1
No fan	52	45	1/2	73	70	67	--	--	69	68	69	--	--
			2-1/2	63	65	64	64	20	68	69	69	69	14

[1] Fan operated only during first 30 minutes of test.

[2] Average of temperature measurements taken at half-hour intervals at midpoint of chamber.

[3] Concentration at all levels was measured every half hour but only first and last readings are presented.

EFFECTS OF GROUND SEAL AND CIRCULATION DEVICES ON GAS CONCENTRATION IN ELONGATE CHAMBERS

During November 1961, rows of planted pines in a nursery were fumigated in elongate chambers to determine:

1. The effect of forced circulation on gas concentration within the horizontal expanse of the chamber.

2. The effect of bare ground versus a ground tarp on gas concentration.

Methods

Mixed mugho and lodgepole pines in four 25-foot rows were enclosed in paired chambers 25 feet long, 5 feet high, and 4 feet wide. Circulation was provided in two chambers with two 8-inch fans positioned at opposite ends of the chamber and directed perpendicularly to the line of flow of the introduced gas. No means of circulation was provided in the other two chambers. From one chamber in each series ground cloths were removed, and the sides and ends of the chamber jackets were buried in small trenches surrounding the chambers. Gas concentration and temperature measurements were recorded every 30 minutes following gas introduction. Gas sampling lines were located at midchamber height at three locations equally spaced along the side of the chamber; thermometers were also placed at midchamber height but at only two locations, one-third of the distance in from the end of the chamber. Gas was introduced at the rate of 4 pounds per 1,000 cubic feet. Exposure time varied because time and temperature was expressed as a single unit--vapor pressure x time equivalents, derived by accumulating the average vapor pressure during 30-minute periods.

Results

Because of a shortage of suitable rows of pines, replications of the tests were not possible. Because of this and the difference in exposure periods, the data were not statistically analyzed. The results are presented in table 2. From this table it can be seen that there was a strong trend toward uniform horizontal gas distribution. Gas loss was slightly higher in those chambers without ground tarps, but they were subjected to longer exposure periods. Previous tests showed that the rate of gas loss is linear in relation to elapsed time.

Table 2.--Effects of ground seal and circulation devices on methyl bromide gas concentration (at rate of 4 pounds (64 ounces) per 1,000 cu. ft.) in 25-foot elongate cubical chambers; Bothell, Wash., November 1961

Circulation	Ground seal	Average chamber temperature[1/]	Time of reading following gas introduction[2/]		Gas concentration at three horizontal sampling positions (per 1,000 cu. ft.)				
					Left third	Mid-point	Right third	Average	Total gas loss
		Degrees F.	Hr.	Min.	Ounces	Ounces	Ounces	Ounces	Percent
Fans[3/]	Tarp	42	0	30	57	57	57	--	--
			3	00	56	56	56	56	13
No fans	No tarp	43	0	30	50	54	55	--	--
			3	15	48	48	48	48	25
Fans[3/]	No tarp	38	0	30	55	56	57	--	--
			3	30	48	48	48	48	25
No fans	Tarp	44	0	30	54	56	55	--	--
			2	30	51	51	51	51	20

[1/] Average of temperature measurements taken at 30-minute intervals at two points at midchamber heights, equally spaced along chamber.

[2/] Treatment time varied according to time and temperature in order to obtain similar overall treatment effects.

[3/] Two 8-inch fans, each positioned at opposite ends of the chamber, and operated for 30 minutes after introduction of gas.

EFFECTS OF TIME, TEMPERATURE, AND GAS CONCENTRATION ON GAS RETENTION

Records from tests to determine factors affecting shoot moth mortality were examined to determine whether gas retention is reduced when the chambers are subjected to higher temperatures. Vapor pressure increases with temperature, and this increased pressure might account for increased gas loss.

Methods

During March 1961, 36 Scotch pines and 36 mugho pines were fumigated using the following treatment factors: two predetermined chamber temperature ranges of 45° to 65° F. and 65° to 85° F.; 4, 5, and 6 pounds of methyl bromide per 1,000 cubic feet; and three treatment periods of 2, 2-1/2, and 3 hours. Temperature measurements were taken every 30 minutes; gas concentration was measured 30 minutes after the start of fumigation and 30 minutes prior to the termination of fumigation. One tree of each species was treated with a separate gas concentration, time period, and temperature range in each of two blocks. Actual temperature ranges were determined by averaging the temperature recordings for the 30-minute periods. In each of the 72 observations, minimum and maximum temperatures did not exceed their respective ranges. Five- and ten-foot cubical chambers were used at random.

Results

Data are shown in table 3. No significant differences in gas retention were found between temperature, time, or rates of gas concentration. Results of subsequent tests during late spring and fall using similar temperature ranges substantiated these findings.

Table 3.--Effects of two temperature ranges and three time periods on methyl bromide gas concentration (at rates of 64, 80, and 96 ounces per 1,000 cu. ft.) in cubical chambers; Seattle, Wash., March 1961

Time (hours)	Treatment group[1]	Gas concentration (per 1,000 cu. ft.)[2]: Low temperature range (45° to 65° F.)[3] 64 oz.	Low temperature range 80 oz.	Low temperature range 96 oz.	High temperature range (65° to 85° F.)[3] 64 oz.	High temperature range 80 oz.	High temperature range 96 oz.
		Ounces					
2	1	53	82	86	62	76	64
	2	57	64	78	41	59	90
	3	48	75	83	60	74	81
	4	52	40	84	55	72	78
	Average	53	65	83	55	70	78
2½	1	49	80	78	58	73	79
	2	59	75	74	50	70	85
	3	52	72	82	54	65	81
	4	50	69	79	48	70	77
	Average	53	74	78	53	69	81
3	1	52	77	85	35	59	90
	2	55	72	78	54	70	74
	3	46	67	78	50	67	80
	4	61	48	90	50	66	82
	Average	54	66	83	47	65	81
		Percent	Percent	Percent	Percent	Percent	Percent
Gas loss:							
2-hour period		17	19	14	15	12	18
2½-hour period		18	7	19	17	13	16
3-hour period		16	17	14	26	18	16

[1] Each treatment group consisted of six trees.

[2] Gas concentration was measured one-half hour after start of test and one-half hour before evacuation but only latter measurements are presented.

[3] Temperature recorded every 30 minutes.

EFFECTS OF CHAMBER TYPES ON CHAMBER TEMPERATURE AND GAS CONCENTRATION

The cylindrical chamber was compared with the standard cubical chamber to determine differences in chamber temperature and gas concentration associated with type of chamber.

Methods

A 5-foot-diameter cylindrical chamber was paired with a 5-foot-square cubical chamber, both of which enclosed pines of similar size. Gas concentration and internal and external temperatures were measured every 30 minutes. Concentration measurements were taken at three chamber positions: upper, middle, and lower chamber thirds. The tests were run for 2 hours at 3 pounds of methyl bromide per 1,000 cubic feet. Each test was repeated three times.

Results

Gas concentrations were within 1 ounce of theoretical concentrations in the cylindrical chambers, but 6 to 8 ounces less in the cubical chamber. No apparent difference in gas concentration with time or chamber position was found. No difference in chamber temperatures was observed between the two chamber types, nor was there a noticeable difference in internal and external temperatures between chambers.